sectional structure of a main portion of the reverse blocking IGBT according to the related art. In FIG. **17**B, the y-axis indicates the thickness of the reverse blocking IGBT illustrated in FIG. **17**A and the x-axis indicates the electric field intensity distributions when the forward voltage is applied and when the reverse voltage is applied. The distance of the y-axis means the distance to an emitter direction when the rear surface of the substrate (the interface between a p collector region **10** and a collector electrode **11**) is 0 (zero). In the reverse blocking IGBT illustrated in FIG. **17**A, buffer layers **201** and **202** which have the same conductivity type and high impurity concentration are provided at the interface between an n^- drift region **1** and a p base region **2** and the interface between the n^- drift region **1** and the p collector region **10**, respectively. Therefore, it is possible to achieve an IGBT having a forward breakdown voltage value and a reverse breakdown voltage value which are equal to each other (for example, see JP 2002-532885 W).

[0013] As an IGBT with improved electrical characteristics, a device has been proposed in which a high-impurity-concentration region that has the same conductivity type as an n^- drift region is provided at least a portion of the boundary between a p base region and the n^- drift region. According to this structure a channel length is reduced and a voltage drop in an on state is reduced (for example, see JP 09-326486 A).

[0014] As another IGBT with improved electrical characteristics, the following device has been proposed. A short lifetime region is provided in a portion of an n drift region close to a p collector region. The short lifetime region is an n-type region and has a higher impurity concentration than an n base layer. According to this structure, it is possible to reduce the leakage current of a non-punch-through (NPT) IGBT (for example, see 09-260662 A).

[0015] As another IGBT with improved electrical characteristics, a device has been proposed which includes a second-conductivity-type collector region and a first-conductivity-type field stop region that is formed in a first-conductivity-type semiconductor substrate, has a higher impurity concentration than the first-conductivity-type semiconductor substrate, and is separated from the second-conductivity-type collector region (for example, see JP 2002-246597 A). In JP 2002-246597 A, even when a partial deficiency occurs in the collector region, an increase in the voltage drop characteristics in an on state or the deterioration of the breakdown voltage characteristics is suppressed.

[0016] As a bidirectional IGBT with improved electrical characteristics, the following device has been proposed. Gate electrodes are provided in trenches which are formed in two main surfaces of a semiconductor substrate through gate oxide films and trench MOS gate (an metal-oxide-semiconductor insulated gate) structures (hereinafter, referred to as trench gate MOS structures) are formed on the two main surfaces of the semiconductor substrate. A buffer layer which has the same conductivity type as a drift region and has a higher concentration than the drift layer is provided at the interface between the drift region and a base layer on the two main surface sides of the semiconductor substrate. In addition, a depletion layer which is spread to the drift region when an off-voltage is applied extends sufficiently to reach the high-concentration buffer layer. This structure is a punch-through structure. According to this structure, it is possible to improve the breakdown voltages in two directions to the same level and to remove an oscillation waveform when the device is turned off. In addition, it is possible to control the gate in two directions (for example, see JP 2001-320049 A).

[0017] As a reverse blocking IGBT with improved electrical characteristics, a device has been proposed in which a second trench groove is formed on the collector electrode side, an oxide film is coated on the surface of the second trench groove, the second trench groove is filled with polysilicon, a second n buffer region is formed in a portion interposed between the second trench grooves, and a depletion layer is spread to an n^- drift region over the second n buffer region when a reverse bias is applied, thereby obtaining the reverse breakdown voltage equal to the forward breakdown voltage using a PT structure (for example, see JP 2003-318399 A).

[0018] However, in the reverse blocking IGBT disclosed in JP 2002-319676 A, the reverse breakdown voltage is likely to be lower than the forward breakdown voltage. Hereinafter the reason will be described. The planar reverse blocking IGBT requires the p^+ isolation region which extends from the front surface of the semiconductor substrate to the p^+ collector region on the rear surface side in order to ensure the reverse blocking capability. A drive diffusion (heat treatment) which is required to form the p^+ isolation region is performed in an oxygen atmosphere at a high temperature for a long time in order to prevent the surface roughness of the n type silicon substrate. For example, the diffusion time of the heat treatment is about 100 hours at a temperature of 1300° C. in a device for a breakdown voltage of 600 V and is about 200 hours at a temperature of 1300° C. in a device for a breakdown voltage of 1200 V.

[0019] When the heat treatment is performed for the silicon substrate in the oxygen atmosphere at a high temperature for a long time, the doped oxygen atom is changed to a donor. In particular, when the silicon substrate has low impurity concentration, the oxygen concentration of the silicon substrate is increased by the influence of the change of the oxygen atom into the donor. Since oxygen concentration in the vicinity of the surface of the silicon substrate is reduced by outward diffusion, the impurity concentration distribution of the silicon substrate is low in the width (depth) range of a few micrometers to tens of micrometers from two main surfaces of the substrate in the depth direction and is high at the center of the substrate. The manufacturing processes of the reverse blocking IGBT include a process of forming a predetermined MOS gate structure and an aluminum electrode film on the front surface, a rear surface grinding process of reducing the thickness of the n drift region to a value required for a breakdown voltage while reducing the on-voltage, and a process of forming the p^+ collector region and the collector electrode. The amount of grinding of the rear surface of the silicon substrate in the rear surface grinding process is very large, that is, equal to or more than half the original thickness of the silicon substrate. Therefore, as described above, the silicon substrate which is affected by the change of the oxygen atom into the donor has an impurity concentration distribution in which, after the rear surface grinding process, the impurity concentration is high on the collector side for which the rear surface grinding is performed and is obliquely reduced on the emitter side by the influence of outward diffusion in the width (depth range) of a few micrometers to tens of micrometers from the front surface of the substrate in the depth direction.

[0020] As a result, since the impurity concentration of a collector-side portion of the n drift region is higher than the impurity concentration of an emitter-side portion of the n drift